Millennium Ecosystem Assessment: Treatment of Uncertainty
Notes for Delta Independent Science Board prepared by Richard B. Norgaard
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While the IPCC provided instructions up-front for authors on the treatment of uncertainty, the Millennium Ecosystem Assessment (MA) process did not provide explicit instructions. The IPCC instructions were circulated and discussed during meetings, but the sense from discussions about uncertainty during the MA meetings was that the IPCC instructions were "great" but unworkable since probabilities could not realistically be assigned given the nature of ecological modeling.

The MA, however, did adopt a definition of uncertainty used by the IPCC.

From the Millennium Ecosystem Assessment Framework Report (2003)
Glossary 2003 (risk and likelihood are not listed, nor accuracy, etc.)

> *Uncertainty: An expression of the degree to which a future condition (e.g., of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behavior.*

Uncertainty, however, was always a major issue of discussion, and these discussions resulted in a section of the Summary on Conditions and Trends (volume 1, page 22) that reads:

Knowledge and Uncertainty
The experience of this assessment has been that it is hard to demonstrate, quantitatively and unequivocally, the widely accepted and intuitive link between ecosystem changes and changes in human well-being. There are several reasons for this. First, the impacts of ecosystem change on well-being are often subtle, which is not to say unimportant; impacts need not be blatant to be significant. Second, human well-being is affected by many factors in addition to the effects of ecosystem services. Health outcomes, for example, are the combined result of ecosystem condition, access to health care, economic status, and myriad other factors. Unequivocally linking ecosystem changes to changes in well-being, and vice versa, is especially difficult when the data are patchy in both cases, as they usually are. Analyses linking well- being and ecosystem condition are most easily carried out at a local scale, where the linkages can be most clearly identified, but information on ecosystems and human well-being is often only available in highly aggregated form, for instance at the national level. Spatially explicit data with sub-national resolution would greatly facilitate future assessments. [2]

The availability and accuracy of data sources and methods for this assessment were greatest for provisioning services, such as crop yield and timber production. Direct data on regulating, sup- porting, and cultural services such as nutrient cycling, climate regulation, or aesthetic value are difficult to obtain, making it necessary to use proxies, modeled results, or extrapolations from case studies. Data on biodiversity have strong biases toward the species level, large organisms, temperate systems, and species used directly by people. [2, 4, 28]

Knowledge for quantifying ecosystem responses to stress is equally uneven. Methods to estimate crop yield responses to fertilizer application, for example, are well developed, but methods to quantify relationships between ecosystem services and human well-being, such as the effects of altered levels of biodiversity on the incidence of diseases in humans, are at an earlier stage of development. Thousands of novel chemicals, including long-lived synthetic pharmaceuticals, are currently entering the biosphere, but there are few systematic studies to understand their impact on ecosystems and human well-being. [2, 28]

Observation systems relating to ecosystem services are generally inadequate to support informed decision-making. Some previously more-extensive observation systems have declined in recent decades. For example, substantial deterioration of hydrographic networks is occurring throughout the world. The same is true for standard water quality monitoring and the record- ing of biological indicators. [7]

Both ''traditional'' and ''formal'' knowledge systems have considerable value for achieving the conservation and sustainable use of ecosystems. The loss of traditional knowl-edge has significantly weakened the linkages between ecosystems and cultural diversity and cultural identity. This loss has also had a direct negative effect on biodiversity and the degradation of ecosystems, for instance by exceeding traditionally established norms for resource use. This knowledge is largely oral. As significant is the loss of languages, which are the vehicle by which cultures are communicated and reproduced. [17]

The Synthesis Report (2005) also devoted one of its 9 most important questions to "uncertainty."

> 9. What are the most important uncertainties hindering decision-making concerning ecosystems?
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> The MA was unable to provide adequate scientific information to answer a number of important policy questions related to ecosystem services and human well-being. In some cases, the scientific information may well exist already but the process used and time frame available prevented either access to the needed information or its assessment. But in many cases either the data needed to answer the questions were unavailable or the knowledge of the ecological or social system was inadequate. We identify the following information gaps that, if addressed, could significantly enhance the ability of a process like the MA to answer policy-relevant questions posed by decision- makers (CWG, SWG, RWG, SGWG).

Condition and Trends

- There are major gaps in global and national monitoring systems that result in the absence of well-documented, comparable, time-series information for many ecosystem features and that pose significant barriers in assessing condition and trends in eco- system services. Moreover, in a number of cases, including hydrological systems, the condition of the monitoring systems that do exist is declining.
    - Although for 30 years remote sensing capacity has been available that could enable rigorous global monitoring of land cover change, financial resources have not been avail- able to process this information, and thus accurate measurements of land cover change are only available on a case study basis.
    - Information on land degradation in drylands is extremely poor. Major shortcomings in the currently available assessments point to the need for a systematic global monitoring program, leading to the development of a scientifically credible, consistent baseline of the state of land degradation and desertification.
    - There is little replicable data on global forest extent that can be tracked over time.
    - There is no reasonably accurate global map of wetlands.
- There are major gaps in information on nonmarketed ecosystem services, particularly regulating, cultural, and supporting services.
- There is no complete inventory of species and limited information on the actual distributions of many important plant and animal species.
- More information is needed concerning: ▪ the nature of interactions among drivers in particular regions and across scales;
    - the responses of ecosystems to changes in the availability of important nutrients and carbon dioxide;
    - nonlinear changes in ecosystems, predictability of thresh- olds, and structural and dynamic characteristics of systems that lead to threshold and irreversible changes; and,
    - quantification and prediction of the relationships between biodiversity changes and changes in ecosystem services for particular places and times.
- There is limited information on the economic consequences of changes in ecosystem services at any scale and, more generally, limited information on the details of linkages between human well-being and the provision of ecosystem services, except in the case of food and water.
- There are relatively few models of the relationship between ecosystem services and human well-being.

Scenarios

- There is a lack of analytical and methodological approaches to explicitly nest or link scenarios developed at different geo- graphic scales. This innovation would provide decision-makers with information that directly links local, national, regional, and global futures of ecosystem services in considerable detail.

- There is limited modeling capability related to effects of changes in ecosystems on flows of ecosystem services and effects of changes in ecosystem services on changes in human well- being. Quantitative models linking ecosystem change to many ecosystem services are also needed.
- Significant advances are needed in models that link ecological and social processes, and models do not yet exist for many cultural and supporting ecosystem services.
- There is limited capability to incorporate adaptive responses and changes in human attitudes and behaviors in models and to incorporate critical feedbacks into quantitative models. As food supply changes, for example, so will patterns of land use, which will then feed back on ecosystem services, climate, and food supply.
- There is a lack of theories and models that anticipate thresh- olds that, once passed, yield fundamental system changes or even system collapse.
- There is limited capability of communicating to nonspecialists the complexity associated with holistic models and scenarios involving ecosystem services, in particular in relation to the abundance of nonlinearities, feedbacks, and time lags in most ecosystems.

Response Options

- There is limited information on the marginal costs and benefits of alternative policy options in terms of total economic value (including nonmarketed ecosystem services).
- Substantial uncertainty exists with respect to who benefits from watershed services and how changes in particular water- sheds influence those services; information in both of these areas is needed in order to determine whether markets for watershed services can be a fruitful response option.
- There has been little social science analysis of the effectiveness of responses on biodiversity conservation.
- There is considerable uncertainty with regards to the importance people in different cultures place on cultural services, how this changes over time, and how it influences the net costs and benefits of trade-offs and decisions.

Furthermore, Appendix B of the Synthesis Report qualifies expectations with respect to the success of policy and management responses to ecosystem degradation:

Appendix B
Effectiveness of Assessed Responses

A response is considered to be effective when its assessment indicates that it has enhanced the particular ecosystem service (or, in the case of biodiversity, its conservation and sustainable use) and contributed to human well-being without significant harm to other ecosystem services or harmful impacts to other groups of people. A response is considered promising either if it does not have a long track record to assess but appears likely to succeed or if there are known means of modifying the response so that it can become effective. A response is considered problematic if its historical use indicates either that it has not met the goals related to service enhancement (or conservation and sustainable use of biodiversity) or that it has caused significant harm to other ecosystem services. Labeling a response as effective does not mean that the historical assessment has not identified problems or harmful trade-offs. Such trade-offs almost always exist, but they are not considered significant enough as to negate the effectiveness of the response. Similarly, labeling a response as problematic does not mean that there are no promising opportunities to reform the response in a way that can meet its policy goals without undue harm to ecosystem services.

The typology of responses presented in the Table in this Appendix is defined by the nature of the intervention, classified as follows: institutional and legal (I), economic and incentives (E), social and behavioral (S), technological (T), and knowledge and cognitive (K). Note that the dominant class is given in the Table. The actors who make decisions to implement a response are governments at different levels, such as international (GI) (mainly through multilateral agreements or international conventions), national (GN), and local (GL); the business/industry sector (B); and civil society, which includes nongovernmental organizations (NGO), community-based and indigenous peoples organizations (C), and research institutions (R). The actors are not necessarily equally important.

The table includes responses assessed for a range of ecosystem services—food, fresh water, wood, nutrient management, flood and storm control, disease regulation, and cultural services. It also assesses responses for biodiversity conservation, integrated responses, and responses addressing one specific driver: climate change.

Appendix B. Effectiveness of Assessed Responses

Response	Effectiveness: Effective	Effectiveness: Promising	Effectiveness: Problematic	Notes	Type of Response	Required Actors
Biodiversity conservation and sustainable use						
Protected areas				PAs are extremely important in biodiversity and ecosystem conservation programs, especially in sensitive environments that contain valuable biodiversity components. At global and regional scales, existing PAs are essential but not sufficient to conserve the full range of biodiversity. PAs need to be better located, designed, and managed to ensure representativeness and to deal with the impacts of human settlement within them, illegal harvesting, unsustainable tourism, invasive species, and climate change. They also need a landscape approach that includes protection outside of PAs. (R5)	I	GI GN GL NGO C R
Helping local people to capture biodiversity benefits				Providing incentives for biodiversity conservation in the form of benefits for local people (e.g., through products from single species or from ecotourism) has proved to be very difficult. Programs have been more successful when local communities have been in a position to make management decisions consistent with overall biodiversity conservation. "Win-win" opportunities for biodiversity conservation and benefits for local communities exist, but local communities can often achieve greater benefits from actions that lead to biodiversity loss. (R5)	E	GN GL B NGO C
Promoting better management of wild species as a conservation tool, including ex situ conservation				More effective management of individual species should enhance biodiversity conservation and sustainable use. "Habitat-based" approaches are critical, but they cannot replace "species-based" approaches. Zoos, botanical gardens, and other ex situ programs build support for conservation, support valuable research, and provide cultural benefits of biodiversity. (R5)	T S	GN S NGO R
Integrating biodiversity into regional planning				Integrated regional planning can provide a balance among land uses that promotes effective trade-offs among biodiversity, ecosystem services, and other needs of society. Great uncertainty remains as to what components of biodiversity persist under different management regimes, limiting the current effectiveness of this approach. (R5)	I	GN GL NGO
Encouraging private-sector involvement in biodiversity conservation				Many companies are preparing their own biodiversity action plans, managing their landholdings in ways that are more compatible with biodiversity conservation, supporting certification schemes that promote more sustainable use, and accepting their responsibility for addressing biodiversity issues. The business case that has been made for larger companies needs to be extended to other companies as well. (R5)	I	NG B NGO R
Including biodiversity issues in agriculture, forestry, and fisheries				More-diverse production systems can be as effective as low-diversity systems, or even more effective. And strategies based on more intensive production rather than on the expansion of the area allow for better conservation. (R5)	T	NG B
Designing governance approaches to support biodiversity				Decentralization of biodiversity management in many parts of the world has had variable results. The key to success is strong institutions at all levels, with secure tenure and authority at local levels essential to providing incentives for sustainable management. (R5)	I	GI GN GL R
Promoting international cooperation through multilateral environmental agreements				MEAs should serve as an effective means for international cooperation in the areas of biodiversity conservation and sustainable use. They cover the most pressing drivers and issues related to biodiversity loss. Better coordination among conventions would increase their usefulness. (R5,15)	I	GI GN
Environmental education and communication				Environmental education and communication programs have both informed and changed preferences for biodiversity conservation and have improved implementation of biodiversity responses. Providing the human and financial resources to undertake effective work in this area is a continuing barrier. (R5)	S	GN GL NGO C

To read the full report "Human and Well-being Synthesis: A Report of the Millennium Ecosystem Assessment," or for more information regarding the Millennium Ecosystem Assessment please go to: http://www.maweb.org